Reduction of Radiation Dose Received by Surgeons and Patients During Percutaneous Nephrolithotomy: A New Shielding Method

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Purpose: Due to high prevalence of urolithiasis, endourologic interventions have increased for the treatment of patients with urinary stones. During fluoroscopy-guided percutaneous nephrolithotomy (PCNL), the surgeon and the patient are exposed to X-ray and its harmful effects. This study aimed to assess the reduction of the radiation dose received by surgeons and patients after using a new shielding method.

Materials and Methods: In this study, the dose of radiation exposure by the surgeon and patient during PCNL under fluoroscopic procedure with conventional shielding methods was compared to a new shielding method designed by the researcher. For this purpose, shields and lead cones with a thickness of 0.5 mm were used. Also, to evaluate the dose of radiation received by surgeons and patients in different parts of the body, thermoluminescent dosimeters (TLD) were used.

Results: By using the new shielding method, a 37 ± 2% reduction was found in the dose exposure as compared to the conventional shielding method. The maximum reduction in radiation dose was specified to the surgeon's hands, while the lowest reduction in radiation dose was related to the surgeon's thyroid gland. The maximum and minimum reductions in radiation exposure for patients were specified to patients' feet and chest respectively.

Conclusion: There is a significant difference between the total dose received by the surgeons and the patients following the use of the new shielding method and the standard shielding method. The new shielding method can reduce 37 ± 2% of the x-ray received by the patient and the surgeon during fluoroscopy-guided PCNL.

Keywords: endourologic interventions; percutaneous nephrolithotomy; radiation exposure; shielding; urinary stone

INTRODUCTION

Urinary tract stones are the third most common disorders of the urinary tract system after infections and prostate diseases.[(1)] One of the most applicable endourology methods widely used today to treat urinary stones is percutaneous nephrolithotomy (PCNL).[(2)] Percutaneous approach is a common urological procedure for the treatment of urinary stones, tumors and upper urogenital tract stenosis. This method is now popularized because of its considerable benefits including low post-procedural morbidity, high patients' satisfaction, and early return to work and social activities. The efficiency of this method minimizes the need for open surgery. One of the most common methods is fluoroscopy-guided PCNL with X-Ray radiation.[(3)] This method can effectively facilitate dilation of the urinary tract, renal access, as well as stone manipulation. However, long-term fluoroscopic exposures for the localization of calculus necessitate the determination of absorbed radiation dose for physicians, operating room personnel, and patients. Therefore, endourologists, operating room personnel, and urology patients are potentially exposed to X-ray and its-related complications, and therefore should be aware of the safety principles of work with radiation.[(4)] The effects of radiation on increasing the likelihood of cancer and its other destructive effects have been well proven.[(5,6)] The major dose of radiation received by surgeons during PCNL is the radiation dispersed from the patient, radiography bed, and equipment. In this regard, the initial radiation dose plays a minor role in increasing the received radiation dose.[(7)] In other words, the radiation dose exposure can depend on the time of exposure to radiation, distance to the source of radiation, and shielding. It is now hypothesized that the use of shielding is differentially effective on reducing received radiation dose. For this purpose, a new shielding method is proposed in the present study to reduce the dose of radiation received by surgeons and patients.

MATERIALS AND METHODS

This experimental study was conducted between April 2017 and October 2017 at Shahid Beheshti Hospital in Hamadan. The study subjects were selected from pa-

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Table 1. The average dose reached to different parts of the body in the first and second stages in millisieverts and The percentage of radiation dose reduction after applying the new shielding method

Area	The dose reached the chips in the first stage (mSV)	The dose reached the chips in the second stage (mSV)	Radiation dose reduction	*P*-values
Surgeon group				
Hand	0.2 ± 0.06	0.1 ± 0.003	55.1 ± 8.2 %	*P* < .001
Foot	0.1 ± 0.007	0.05 ± 0.004	54 ± 1.7 %	*P* < .001
Chest	0.07 ± 0.005	0.04 ± 0.002	48.4 ± 7%	*P* < .001
Thyroid	0.073 ± 0.002	0.072 ± 0.009	0.67 ± 11.9 %	*P* < .001
Forehead	0.1 ± 0.004	0.08 ± 0.006	16.8 ± 7.5 %	*P* < .001
Patient group				
Foot	0.07 ± 0.006	0.03 ± 0.001	51.3 ± 1.9 %	*P* < .001
Chest	0.5 ± 0.02	0.4 ± 0.01	23.2 ± 4.4 %	*P* < .001
Thyroid	0.1 ± 0.002	0.6 ± 0.002	46.4 ± 1.3 %	*P* < .001
Total	0.16710 ± 0.014	0.10760 ± 0.011534	37 ± 2 %	*P* < .001

tients with upper urinary tract stones who were candidates for PCNL. This study was an interventional study in terms of radiation received by surgeons and the staff. The inclusion criteria included patients with pelvic or calyceal stones larger than two centimeters or staghorn calculi. Exclusion criteria included patients with untreated coagulation disorders or active urinary tract infections. The patients were randomly divided into two groups using simple randomization method aided by the Random Number Table. In the first group (using the common shielding method), 30 patients were selected, and the duration of radiation in the first group was calculated. Based on the duration of radiation in the first group, the number of patients in the second group (using the new shielding method) was determined at 23 patients where both groups received the same duration. In the first group, PCNL was performed with the conventional shielding technique including lead apron, thyroid shield and lead glasses, and in the second group, PCNLs were performed by the researcher's new designed shielding method plus conventional shielding technique.

In the routine PCNL procedure, after regional or general anesthesia by the anesthetist, in the frog leg position and using a cystoscope, a 5F ureteral catheter 5F is inserted into the ureter and the corresponding pelvic cavity, and then fixed to the Foley catheter. This catheter is utilized to inject air or contrast agents. The patient is then placed on a special endourology bed compatible with C-ARM in the prone position. To view the renal pelvis, we can use the injection of air or contrast agent into the ureter catheter. The advantage of the air is that, due to the lightness in the prone state, the posterior calyces first appear. After the needle was incorporated in calyx, it was necessary to aspirate it to ensure that air or water was aspirated. Then, from the middle of the needle, an 0.380 inch J-shaped guide wire was passed through the floppy tip to enter the pelvis. Then, the needle entry point was cut about 1cm, the needle was removed, and the guide wire was retained. Eventually, the tract around the guide wire was extended to 30f, using an Amplatz dilator set or a balloon. Both these techniques can be used after passing a guide wire into the system.[8] The patient lay on a stretcher next to the main surgical bed. Then, her flank area was adjusted to about 30 by 30 cm in the window area, and the patient's kidneys were adjusted accordingly.

The kidney itself was in the upper half of the window when the nephrostomy needle was inserted, where its passageway was exposed to the surgeon.

In the first group, the dose received by patients and surgeons during PCNL was considered under conventional

Figure 1. TLD badge opened up.

Figure 2. The protective lead layer designed in the new shielding method.

protective conditions (lead glasses and a simple cover on neck, trunk and lower extremities). First, 20 thermoluminescence dosimetry (TLDs) chips were set on various parts of the surgeon's body (legs, hands, chest, thyroid, and above eyes, with three chips on each part) and 12 chips on different parts of the patient's body (feet, chest, and thyroid). In order to locate TLDs in the desired areas, special TLD badges were designed (**Figure 1**). In the second stage of the implementation of the protective design, a layer of 0.5-mm-thick lead was fitted with a length of 1.8 m and a width of 1.2 m on the patient's bed. The protective shield was hanged from the patient's bed up to 50 cm in the surgeon's side and 10 cm in front of the surgeon. Also, a square hole with a length of 30 cm and a width of 30 cm was created in the protective shield of the lead to facilitate the operative procedure. For easier movement of the shield on the bed, it was designed in three sections. In order to better protect the scatter rays, a lead cone with a height of 15 cm was inserted around the fluoroscopic tube (**Figures 2 and 3**). In order to remove radiation from the results of the study, four TLDs were installed in the personnel rest room, and the radiation dose shown by these chips was deducted from the dosage to the pure dose surgeons received during the first period of the test.

Descriptive analysis was used to describe the data, including mean ± standard deviation (SD) for quantitative variables and frequency (percentage) for categorical variables. Chi square test, independent t-test and Mann-Whitney *U* test were used for the comparison of variables. For the statistical analysis, the statistical software IBM SPSS Statistics for Windows version 22.0 (IBM Corp. Released 2013. Armonk, New York) was employed. *P*-values <.05 were considered statistically significant.

Figure 3. Fluoroscope tube with designed lead connector.

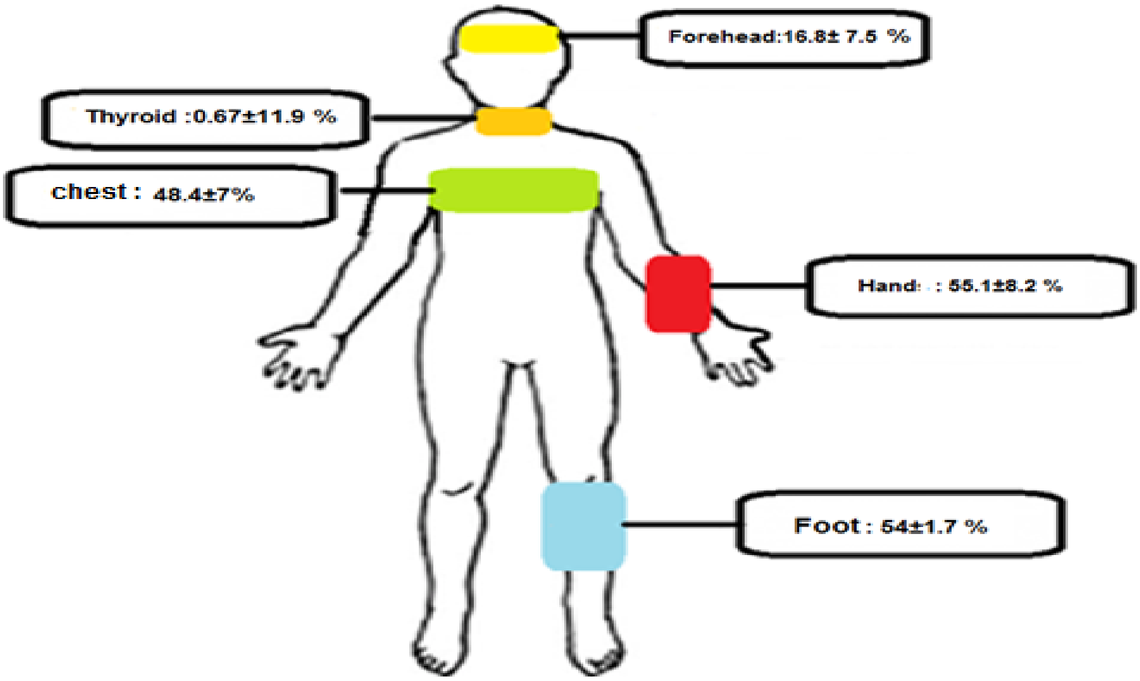

Figure 4. Percentage of received dose reduction of different parts of the body among surgeons after insertion of the new shielding.

RESULTS

All surgical procedures were performed without any special problems or complications related to shielding. Anesthesia and surgery time were not significantly increased (3 minutes required to install the shields). There was no significant difference between the groups in terms of stone removal. The two groups planned for standard protective method and the new shielding method were comparable in the mean age (48.5 ± 2.6 years versus 45.0 ± 2.2 years, $p = .456$) and mean body mass index (25.6 ± 1.5 kg/m^2 versus 26.4 ± 1.6 kg/m2, $p = .789$). The number of surgeries in the two groups was 30 and 23 respectively with a total mean radiation time of 1482 and 1587 seconds, respectively, indicating 106 seconds (7%) longer radiation duration in the latter group. Thus, to match the two groups, this extra amount was deducted from the amount of charge received in the second group. In the first and second groups, the average tube potential of the fluoroscope was 79.3KV and 78.8KV, respectively, with no meaningful difference ($p = .124$). Also, the mean currents in the tube of fluoroscope were the respective 2.89mA and 2.86mA with no significant difference ($p = .897$). The average distance between the lower limbs of the surgeon and the fluoroscope tube was 41.3cm in both groups. In the two groups with the standard protective method and the new shielding method, the average dose reached the total dosimeters of 0.16710 ± 0.014 mSV and 0.10760 ± 0.011534 mSV respectively ($P < .001$). In both groups, the highest doses were recorded in the dosimeters on

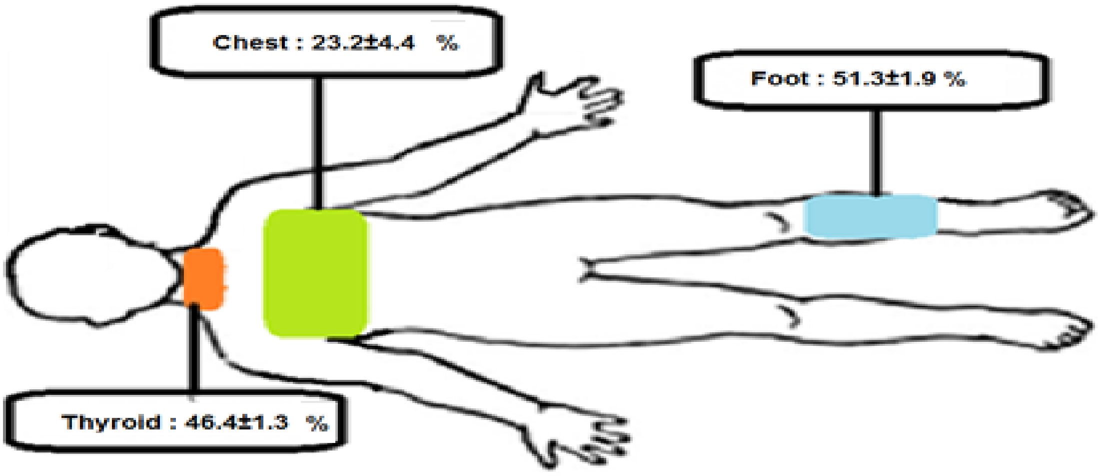

Figure 5. Percentage of received dose reduction of different parts of the body among patients after insertion of the new shielding.

patients' chest, the second recorded in the dosimeters on surgeon's hands and the lowest doses in the patient's leg (**Table 1**). In general, the maximum reduction in radiation dose was specified to the surgeon's hands (55.1 ± 8.2%) followed by the surgeon's foot (54.0 ± 1.7%), while the lowest reduction in radiation dose was related to surgeon's thyroid gland (0.67 ± 11.9%) (**Table 1 and Figure 4**). The maximum and minimum reductions in radiation exposure for patients were specified to patients' feet (51.3 ± 1.9%) and chest (23.2 ± 4.4%) respectively (**Table 1 and Figure 5**).

DISCUSSION

With the advent of PCNL surgery, as one of the major treatments for upper urinary tract stones, the association of this surgical technique with radiation emitted from the fluoroscope was taken into consideration. The presence of a fluoroscope device has led to the progression of PCNL surgery. From the early stages of using x-rays in PCNL surgery, harmful effects of radiation on the patient and surgeon have been a challenge for urologists. The task was first to identify these harmful effects and, second, to minimize these effects. For this reason, researchers have taken steps to find ways to reduce radiation by the patient and surgeon.

Reducing the amount of radiation reaching the surgeon and the patient is very important. A urologist will perform more than 100 PCNL surgeries annually for several consecutive years. Therefore, the need to protect the surgeon against X-rays is felt more than ever

On the other hand, urinary stone is a recurrent disease where patients may need to have urological surgeries with X-ray intervention. It is also important for infants with metabolic disorders or cystinuria to undergo multiple PCNL surgeries during their life. Moreover, the operating room staff and the relevant anesthesia department staff are directly or indirectly exposed to X-ray damage. Observing the safety principles to create a work environment with the highest safety factor is necessary to continue the work of this group of medical personnel. Accordingly, we thought to introduce a new method to protect the surgeon, the operating room staff, and the patients against the x-rays of the fluoroscope. In general, through the new shielding method, we found a 37 ± 2% reduction in dose exposure as compared to the conventional shielding method. The maximum dose reduction in the surgeon's body was observed in the hands and the least in the thyroid. Consequently, we found the effect of the new shielding method on reducing the radiation dose in the parts closer to the radiation tube. The least distance of the tube in the surgeon's body was related to the surgeon's hand and foot, which has the highest dose reduction, and the maximum distance between the tube and surgeon's body was related to the surgeon's thyroid and forehead, where the dosage is minimized by applying the new shielding method. In the patient's body after applying the new shielding method, the maximum and minimum dose reduction was related to the patient's leg and chest, respectively. The square cavity formed on the lead layer used on the patient's bed has dimensions of 30 × 30 cm. In addition, PCNL surgery sometimes requires a 30-degree angle fluoroscopy, and in some patients the new shields did not cause any problems for fluoroscopy at a 30-degree angle. It seems that a lower reduction in the dose of radiation received by the patient in the chest area might be due to the large size of this cavity. It can also be suggested that another reason for lowering the amount of radiation received in the thyroid region and the forehead could be related to the large cavity in the middle of the lead layer. Because of this large cavity, there is a possibility of greater scattering of radiation, and the surgeon's forehead and thyroid are also in the direction of the radiation emitted out of this square region which is formed on the lead layer. Giblin et al. examined the amount of radiation emitted by surgeons during ureteroscopy and cystoscopy aided by fluoroscope. In this study, a 0.5-mm thick lead layer was used between the surgeon and the patient, which was eventually reported to decrease the radiation dose reached by the surgeon by 70 times.[9] The mentioned study focused solely on reducing the radiation received by the surgeon, and the shield embedded to protect the surgeon causes a limitation for surgical activity. In our study, a survey was conducted on the amount of radiation emitted by a surgeon and a patient in a PCNL surgery. It should be noted that the new shielding designed in this study does not interfere with surgical procedures. In a study by Yang et al in 2002, a new shielding method was introduced in which a 0.5-mm thick lead layer was placed between the surgeon and the patient, and the dose of radiation received by the chest and forehead of the surgeon were measured before and after shielding. The study was performed on 6 patients in each group. According to the findings, the surgeon's dose reduction was 76% and the dose reduction in the surgeon was 96%.[10] In our study, we have a larger sample size and our shielding method is different and designed to protect all parts of the surgeon's body and patient from radiation. Also, in contrast to the study by Yang where only two points on the surgeon's body were considered, our study examined five points of the surgeon's body to measure radiation dose. In a study by Politi et al., in 2012, the effect of using a new type of protective coating around the patient's body to absorb dispersed radiation from the patient's body was studied to reduce the dose received by the operator during coronary artery angiography. The study was performed on 60 patients. A sterile lead shield was used with dimensions of 35 × 45 cm covered around the radial artery (from the access point to the chest wall). Dosimetry through the TLD chips inserted in various points of the cardiologists' body (wrist, chest, thyroid, and eye) showed that the mean dose administered to the whole body of the operator decreased from 367.8 ± 105.4 mSV to 282.8 ± 32.55 mSV after using a new protective method. Therefore, a 23 percent reduction in personnel dose was evident in their method. Reducing the dose delivered to various parts of the body was also evaluated by using this new protective method between 13% and 34%.[11] In a study by Iball et al., the effect of a new shielding method on patients' reception of the dose during CT scan was studied. In this study, a lead layer around the abdomen and pelvis of the patient during chest CT scan was used, and the authors reported that the amount of radiation in different phases of the study ranged from 5% to 73%.[12]

CONCLUSIONS

Based on the findings of this study, there is a significant difference between the total dose received by the surgeons and the patients following the use of the new shielding method and the standard shielding method. The new shielding method can reduce 37% ± 2 of the x-ray received by the patient and the surgeon during PCNL surgery under fluoroscopic procedures. Dose reduction in different parts of the body of the surgeon was 34.7 ± 2.7%, and in different parts of the patients' body was 40.3±2.5%. The highest reduction in radiation dose in the surgeon was specified to hands, while the lowest reduction in radiation dose was related to the surgeon's thyroid gland. The maximum and minimum reductions in radiation exposure for patients were specified to patients' feet and chest respectively. Based on the findings of the current study, in order to reduce the dose of radiation received by the patient, surgeon and operating room personnel, it is recommended that in all PCNL surgeries under fluoroscopic procedures, the new protective method introduced in this study be adopted to reduce the harmful effects X-ray.

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CONFLICT OF INTEREST

The authors report no conflict of interest

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